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16. Abstract

Land use classes based on the interpretations of ERTS-1 imagery are being defined and tested by University of Minnesota personnel with the aid of various local, regional, state, and federal agencies that have land management and planning responsibilities in Minnesota. Classification and test areas for urban, extractive industry, and agricultural land use have been examined with high levels of accuracy. When base line information exists, the ERTS-1 data extraction times are comparable to other sources; however, greater detail was extracted from ERTS-1 than the comparison data base.

Full scale test areas are being developed to include all classes of land use when surface water and wetlands classes are finalized.

17. Key Words (Selected by Author(s))	18. Distribution Statement
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Figure 2. Technical Report Standard Title Page

PREFACE

The work described in this report is aimed at evaluating ERTS-1 imagery as a data source for improving and updating the Minnesota Land Management Information System (MLMIS). The primary areas of concern during this reporting period have been in developing and testing operational definitions for information classes based on ERTS-1 imagery. Persistent efforts are being made to develop and improve procedures for transferring ERTS-1 image content information from the interpretation phase to the land management information file. These are long and tedious steps that are essential for successful evaluation of massive information collecting systems such as ERTS. Only in this way is it possible to develop, evaluate, and exploit the use of ERTS imagery in terms of the way information is to be utilized by state and local agencies in their daily resource management operations.

CONTENTS

INTRODUCTION

A spate of recent and pending legislation at the state and federal levels is greatly expanding the demands placed on state and local governmental agencies for responsible land use and land based resource management. The effect is a widening information gulf between the information necessary for intelligent land use planning and management and the information that is available.

Three problems must be solved before this widening information gulf can be closed. First, the information must be current and updated at critical intervals for effective land use planning and management. Second, the data must be in a form and of a quality that facilitates their employment in the daily operations of the information users. Finally, the information must be accessible to the users in sufficient quantity and minimal effort so that planners and managers are encouraged to employ the proper information in planning, policy formulation and management.

ERTS-1 type systems of repeated surface information collection are capable of aiding the solution of the first problem if welded to solutions to the other two. The Minnesota Land Management Information System (MLMIS) is aimed at solving the third problem.

The Minnesota State Planning Agency with the assistance of the University of Minnesota Center for Urban and Regional Affairs and cooperating personnel from the Departments of Forest Resource Management, Geography, and Soil Science are attempting to solve problem two by analysis of ERTS-1 imagery to determine if the form and quality of the satellite imagery is commensurate with some of the information needs of planners, policy makers, and managers in Minnesota.

This effort is experiencing expanding support by various federal, state, and local resource management agencies in Minnesota. Particularly important is the interest and support of the Minnesota Department of Natural Resources Bureau of Environmental Protection, which is assisting by defining its information needs in terms of form and quality. Their role in resource and land management makes them one of the more important potential users of ERTS-1 derived land use information.

WORK PROGRESS AND PROGRAMS FOR NEXT REPORTING INTERVAL

A variety of ERTS-1 products are employed in this work effort. The expanding inventory of coverage has yielded complete coverage at least at one season and for several areas 5 to 6 periods of sufficiently cloud-free coverage to allow seasonal evaluation of imagery. Receipt of standing order image regularly runs 4 to 7 weeks behind imagery date. Delays in receipt of 9 1/2" color combined products has been quite long with distinct geographic biases in the pattern of areas with very long delays. Images overlapping state borders seem to have a much higher probability of being produced than images from central Minnesota.

The Institute of Agriculture Remote Sensing Laboratory is producing specialized color combined images on their I^2S color combiner. These images have been employed to varying degrees in the reports that follow.

Work progress and programs in the different work areas are included in the succeeding chapters. Complete reports for forestry applications and wetlands will be included in the next Type I report.

Urban Land Use Classification With ERTS-1 Imagery

James Gamble, Dwight Brown, and John Harrington

Typically, the classification of land use in the past has been accomplished through the use of air photos and by field observation. The dynamic aspects of metropolitan expansion and contraction tend, however, to rapidly outdate land use information. Furthermore, the cost of frequent updating is usually prohibitive. As a result, users have been forced to rely on land use data which has an increasing probability of inaccuracy through time.

Conceptually, imagery from ERTS-1 offers a potential solution to these user problems. ERTS-1 is capable of continuous monitoring and may cost less than the more traditional methods. Since the State of Minnesota has an operational data base, the Minnesota Land Management Information System (MLMIS), the prospect of updating it from ERTS-1 data is an intriguing possibility. With this in mind, an analysis of the Twin Cities Metropolitan area was undertaken to test the feasibility of ERTS-1 metropolitan land use classification - its accuracy and cost.

The study began with the selection of a test area from a color combined ERTS-1 image of October 6, 1972. An area in South Minneapolis was chosen to test the correlation between differences in colors and intensities and actual land use patterns. The strength of this relationship indicated that colors and intensities did, in fact, constitute differing land uses. Actual land use in the test area was determined from NASA provided RB 57 air photos and by field observation. Structural surfaces were evaluated in terms of structure density within a square forty acre cell centered on the ground truth sampling point.

Ultimately nine ERTS-1 classes were operationally defined based on this ground truth. The classes are as follows:

1. Commercial Core - CBD, absence of trees, multi-level buildings. Threshold of Detection - about 10 buildings per forty acres.

2. Industrial Core - Railroad oriented, usually near commercial core, some vegetation and parking facilities. Threshold of Detection - 10 to 15 buildings per forty acres.

3. Commercial/Industrial Strip - Road or intersection oriented, low buildings, more abundant parking, proximity to residential areas. Threshold of Detection - 15 to 20 buildings per forty acre cell.

4. High Density Single Family Residential Units - Abundance of mature trees and vegetation, square street grid predominates. Threshold of Detection - over seventy five buildings per forty acre cell.

5. Low Density Single Family Residential Units - Large lots, abundant vegetation and trees. Threshold of Detection - ranges from ten to twenty units per forty acre cell, depending on contrast with surrounding environment.

6. Mixed Multiple and Single Family Residential Units - Small lots, proximity to commercial core, abundance of two and three story multi-family units, some mature trees. Threshold of Detection - over 85 units per forty acre cell.

7. Urban Open Space - Golf courses, parks, cemeteries, Vegetation predominates. Threshold of Detection - at least 8 acres in size.

8. Extractive - Absence of vegetation, exposed soil, sand and gravel pits predominate. Threshold of Detection - at least 15 acres in size.

9. Non-Urban - Includes all land uses not specified in other classes, usually cultivated or open agricultural land. Threshold of Detection - 15 acres in size.

The classes were chosen with reference to MLMIS, United States Geological Survey, and Twin Cities Metropolitan Council land use categories. Since MLMIS classes were regarded as too general, USGS classes as difficult to operationalize, and the Metropolitan Council's classes as too detailed, none of the ERTS-1 classes were based solely on these previously existing schemes. Rather, the ERTS-1 classes were hybrid in a effort to take full advantage of the available information.

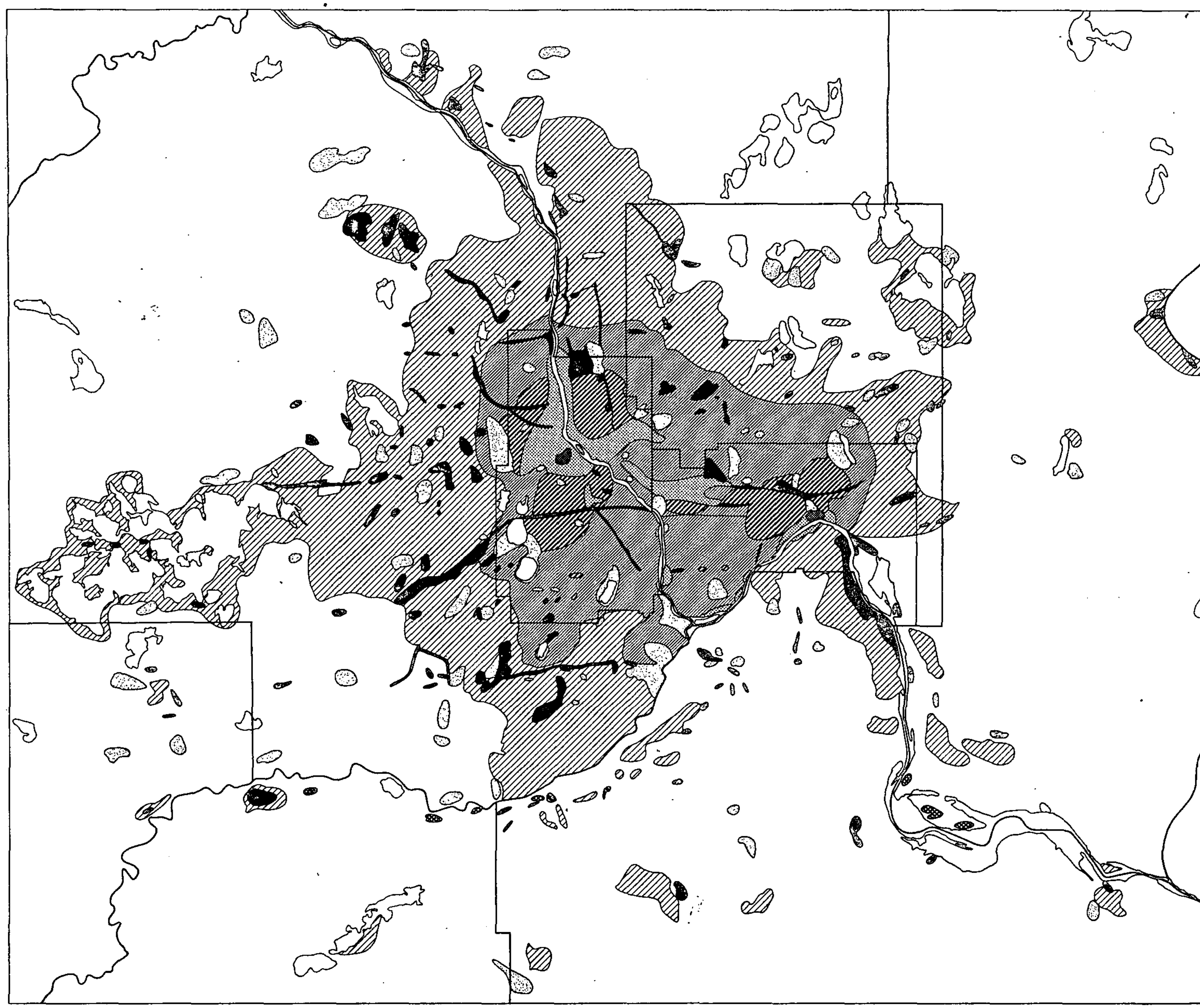
Difficulties in operationally defining the ERTS-1 classes are most apparent in cases in which surface cover or apparent use conflicted with actual use. For example, in which class does parkland belong when it is part of an arsenal facility? A concomitant problem is that of thresholds of detection. Minimum thresholds of detection vary from class to class and are influenced by the contrast in surrounding land uses. Results from analysis of ERTS-1 land use data should therefore be seen in light of these problems.

ERTS-1 color combined images of the Twin Cities Metropolitan area from October 6, 1972, and February 9, 1973 were used as the basis for a land use analysis of the area. The images were enlarged to a scale of 1:125,000 and mapped (see attached map). In order to test the accuracy of this interpretation, samples approximately inversely proportional to the areal extent of each class were taken. A random dot template was used to generate the samples because dot sampling was judged to be less susceptible to the edge problems created by manual alignment error than was grid cell sampling. The samples were checked against air photos and field observations. The results are shown in Table 1. The percentage of correct land use assignments ranged from a low of 67% in the Low Density Single Family class to a high of 81% in the Commercial Core class (see Table 1).

ERTS I

METROPOLITAN LAND USE CLASSES
Twin Cities, Minnesota

- Commercial Core
- Industrial Core
- Commercial/Industrial Strip
- High Density, Single Family Residential Units
- Low Density, Single Family Residential Units
- Mixed Single and Multiple Family Residential Units
- Urban Open
- Extractive
- Non-urban



Scale: 1 inch = 5.92 miles

TABLE 1

ERTS-1 CLASSES

Base Line Data	1	2	3	4	5	6	7	8	9	10	11
1. Commercial Core	81	13		94			1	1			
2. Industrial Core	18	200	7	225	9		12	21	1		
3. Commercial/Industrial Core			869	869	38	71	19	128	51		1
4. Sum of 1-3	99	213	876		47	71	32		52		
5. High Density Single Family		23	86	104	429	22	33	486	153		
6. Low Density Single Family			177	177	18	665	2	683	71	2	8
7. Mixed Multiple and Single Family	1	4	14	19	33		260	293	19		
8. Sum of 5-7	1	27	277		490	687	295		243	2	
9. Urban Open Space		10	88	98	45	93	10	148	998	8	
10. Extractive			6	6						53	
11. Other Land Use			6	6	11	112		123	76	12	391
N	100	250	1253		583	963	337		1369	75	400
% correct	81	80	693		73.5	67	77.1		72.8	70.7	97.7
% in 4	99	85	69.9		8.2	7.3	9.4		3.7	0	.2
% in 8	1	10.8	22.1		84.1	71.4	87.5		18.6	2.5	2

Though the table represents the general accuracy of ERTS-1 classification, it obscures some important findings. For example, there appears to be a lack of accuracy in the assignment of areas to the Commercial/Industrial Strip class. The map, however, reveals that this class is often linearly arranged, thereby increasing its chances of being distorted by geometric imperfections in the film and projection equipment. The distortion caused alignment problem is evident in all classes and can, in general, be said to cause loss of accuracy away from the center of the map. Even with the alignment problem, errors in class designation are generally not gross. Rather, most errors fell into similar classes (see Table 1). For example, of the one hundred dots judged by ERTS-1 to be Commercial Core, only one actually belonged in a residential class. Since ERTS-1 classes are essentially land use intensity and density functions, it seems logical to assume that these errors would fall into similar classes. In fact, air photos reveal that these ERTS-1 errors are related to the problem of surface cover versus surface use. In this regard, ERTS-1 classification is undoubtedly more useful for determining surface cover than it is for determining how it is used.

Tests to determine the threshold detection for urban areas were carried out in three areas of the state, the Northwest, South-Central, and Southeast. Band 7, bulk 70mm imagery was used for each area and all three scenes were snow covered. The results obtained are shown in the following table.

Table II

	Easily Identified		Difficult to Identify	Not Identifiable
	Identifiable CBD	No Visible CBD		
Number of Towns	6	116	31	80
Size Range (1970 Population)	7607-53,983	80-4774	All below 133	All Unincorporated places. No population listed.

All cities and villages that could be located on the bulk 70mm transparencies when projected at a 1:125,000 scale without prior knowledge of their existence were classed as easily identified. All villages that could be found only with <u>a priori</u> knowledge of their locations were classed as difficult to identify. Unidentifiable villages were those places whose presence could not be detected on the image even with knowledge of their exact location.

In rough population terms the easily identifiable places account for over 97.5 percent of the nucleated population in the sample areas. Difficult to identify nucleated settlements account for only about 1.5 percent while the unidentifiable account for less than 1 percent of the nucleated settlement population.

Those findings indicate the threshold of nucleated settlement detection under the conditions of the test to be on the order of ten to twenty dwellings. With the low sun angle, snow-covered imagery, no variations in ease of detection could be distinguished among the three test areas.

Additional tests of one township in Polk County (Northwestern Minnesota flat Lake Agassiz Plain) indicate that 54 of the 95 rural farmsteads could be identified with the low sun angle, snow-covered imagery.

Preliminary analysis of the map and images showed that a number of smaller outlying communities in the Twin Cities metropolitan area could not be readily identified. Further investigation showed that the imagery used (color combined band 5 and 7 for Oct. 6, 1972 and bands 5 and 7 for Feb. 9, 1973) was partially responsible. A February 9, 1973 snow covered band 7 bulk imagery of the Twin City metropolitan area was examined, and six small settled areas, not seen on the color combined images were located. This evidence strongly suggests that the color combining process increases certain thresholds of detection.

At this time, an accurate dollar figure cannot be placed on interpretation costs. At any rate, thirty nine hours were spent on interpreting and mapping the color combined images. Interestingly, interpretation time increased slightly as image analysis experience helped develop a more discerning eye.

The accuracy of ERTS-1 metropolitan land use classes appears to be in the acceptable range and can, perhaps, be increased if locational problems (primarily a function of manual alignment of small dimension mapping units) can be solved. Furthermore, the continuous monitoring capabilities of ERTS-1 offers users current, systematic land use information. To this end, ERTS-1 metropolitan land use information can be used to augment MLMIS data for the Twin Cities area and is being used to distinguish the permeability of the land surface in the Twin Cities.

In summary, the usefulness of ERTS-1 metropolitan land use classification in Minnesota can be and is becoming as real as it is apparent.

Further Work

The first cut interpretation results presented here will provide a base line set of information for the Metropolitan Twin Cities area. The map will then be placed in the hands of primary data users (The Metropolitan Council and various county planning commissions) for evaluation and criticism. The results will be incorporated in a final classification scheme.

The final phase is to carry the ERTS-derived information through to a final users form where data can be accessed and manipulated in The Minnesota Land Management Information System. For this purpose a complete reinterpretation of urban land use, incorporating any necessary changes determined by data users, will be performed. The operational classification schemes of other broad categories of land use included in this report will also be employed in the interpretation of non-urban land use. The test area tentatively includes the entire seven county metropolitan area, and will be based on the best ERTS-1 images received in the first year of operation.

Classification and Mapping of Extractive Land Use in St. Louis County Minnesota with ERTS-1 Imagery

John Harrington, Steven Prestin, Richard Skaggs and Dwight Brown

Extractive industries have played a major economic and social role in the history of Minnesota. The Mesabi Range open pit iron mines are the best known of the extractive industries. The high grade iron ore has been depleted in most of the mines and only a few remain active, e.g., at Hibbing, Minnesota. However, extractive industries continue to be important. Taconite mining operations are becoming increasingly important especially in terms of the large tailings, piles and basins that can result. There is renewed interest in other mining activities in northern Minnesota, especially extraction of copper and nickel from the Duluth gabbro complex. In view of the continued interest in mining and the delicate balance between mining and recreational wilderness area interests in northern Minnesota, it was deemed desirable to investigate ERTS imagery as a means of monitoring mining activity, investigating the time changes in the results of the mining operation, monitoring the progress of mine reclaimation under Minnesota State Statues, and monitoring the interaction between mining and recreational/wilderness activities. Furthermore, the results described in this report can and will be used as the basis for interpreting extractive landscape features for entry into the Minnesota Land Management Information System Study.

The feasibility of using ERTS-1 imagery for mapping extractive features has been quantatively evaluated for a 288 square mile test area in the Mesabi iron range. Extractive features are operationally defined as mines, tailing piles, basins, and gravel pits. Maps prepared from ERTS-1 imagery were compared with a map prepared from the June 6, 1972 NASA RB-57 infrared overflight imagery. Interpretations were also checked from low level aircraft flights in June, 1973. Mapping was done at a scale of 1;120,000. The comparison of maps was made using stratified random sampling.

Four different methods were used to map the water and extractive features in the eight township test areas.

Method 1 - All water and extractive features were mapped from band 7.
Image used - 1057-16311. (September 18, 1972)

Method 2 - All water and extractive features were mapped from band 6.
Image used - 1057-16311. (September 18, 1972)

Method 3 - Water was mapped using band 7, tailings features were mapped using band 6 and mines and gravel pits were mapped using band 5.
Image used - 1057-16311. (September 18, 1972)

Method 4 - Water features were mapped using band 7.
Image used - 1057-16311. (September 18, 1972)
Extractive features were mapped by projecting color combined slides to the appropriate scale. Both single season and seasonal combined slides were used.
Single season - imagery used - 1075-16312. (October 6, 1972)
Multi-season - imagery used - 1076-16370. (October 7, 1972)
1166-16373. (January 5, 1973)

A visual analysis of the four maps prepared from ERTS imagery in comparison with the base map prepared from the NASA RB-57 overflight was used to determine the most accurate of the four interpretation-mapping methods. For every type of extractive feature, Method 4 has the most precision. When Methód 3 is used, precision decreases significantly. Methods 1 and 2 are less precise than Method 3.

The accuracy of Method 4 was tested using a stratified random sampling method. A 28 cell grid was placed on the test area. A random point pattern was placed with a different alignment, on each grid cell six times. For each point, a comparison was made between the map prepared from ERTS-1 (Method 4) and the map prepared from the June 6, 1972 RB-57 overflight (see Map 1). Table 1 shows the number of times that the point comparisons fell into each of the twenty-five mutually exclusive categories.

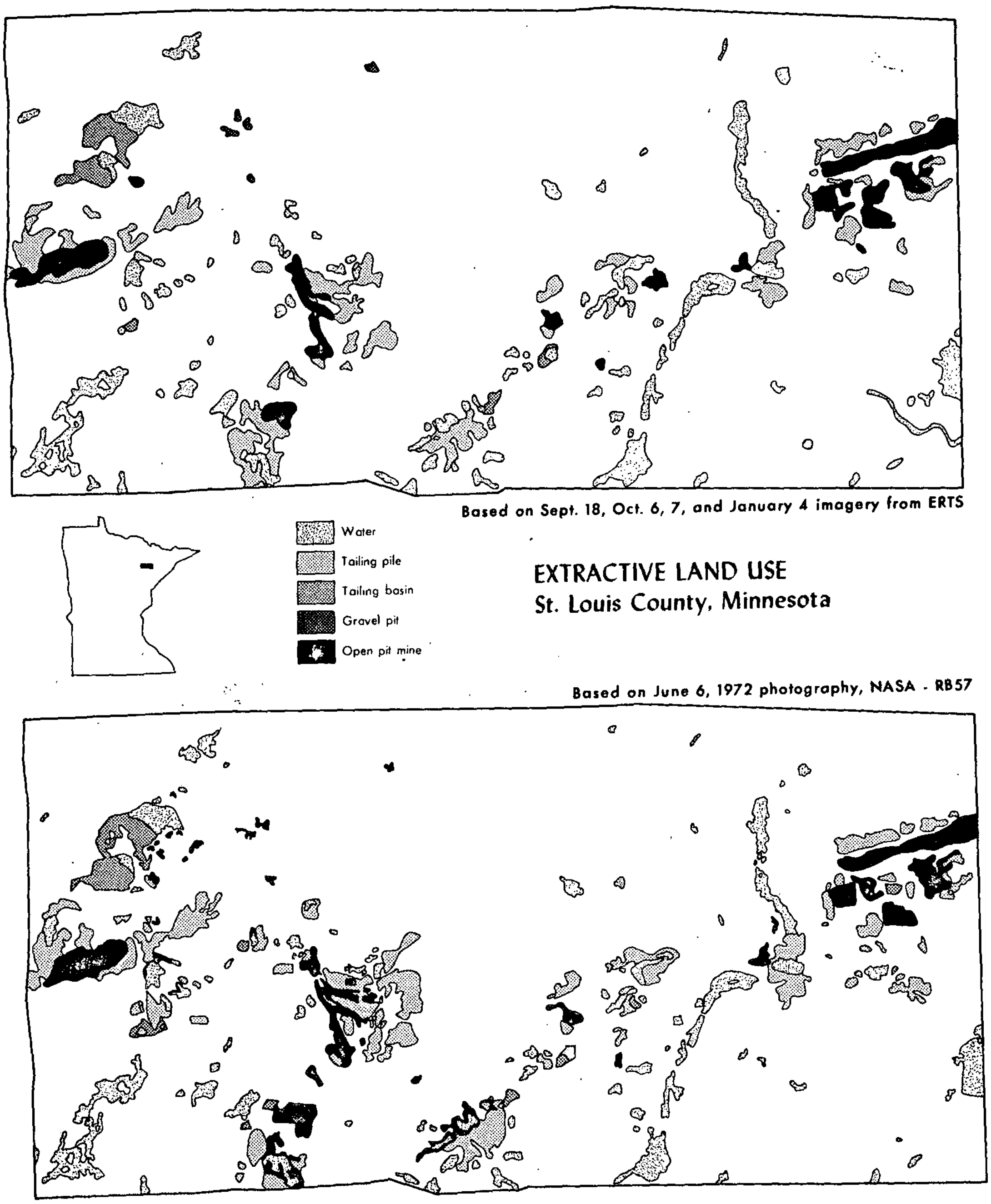
TABLE 1

ERTS / RB-57	Mine	Tailings	Basin	Gravel Pit	Other	Total	% Correct
Mine	84	10			15	109	77
Tailings		129			56	185	70
Basin		1	37		9	47	79
Gravel Pits				4	1	5	80
Other	3	3			2394	2400	99

Open pit mines were mapped with an accuracy of 77% (i.e. 84 out of the 109 points that were mines on the RB-57 map were mines on the ERTS map). Tailings piles were mapped with an accuracy of 70%. Seventy-nine percent accuracy was achieved in mapping tailings basins. Gravel pits were mapped with 80% accuracy.

Map 1 Extractive Land Use

Scale: 1 inch = 3.36 miles



The inaccuracy in the mapping using Method 4 is probably the result of the loss of distinct divisions between features during the color combining process. The distinct divisions that occur on the 70 mm bulk positives become transition zones on the color combined slides. Mapping usually excluded the transition zones. This resulted in a decreased precision in mapping. Evidence for this can be found in the large number of times that mines were mapped as either tailings or other (i.e. not water or extractive). Mapping precision increases with the size of the feature and with increasing distinctiveness from surrounding features. Accuracy in identification of features is only a problem when the feature is less than 10 acres in size. Growth of vegetation on older tailings areas decreases the distinctiveness of the tailings area on the ERTS-1 imagery. This loss in distinctiveness reduces the accuracy obtained in mapping these areas.

Future Work

The findings of this research work are being incorporated into a full scale systems test for Itasca County, described elsewhere in this report.

ERTS-I Applications to the Mapping of
Agricultural Land Use in Minnesota

Linda Graber, Dwight Brown, and John Harrington

Introduction

The purpose of this project is to investigate what facets of agricultural land use may be observed from ERTS imagery and to establish an appropriate classification scheme. Five problems emerge concerning the extent and characteristics of agricultural land:

1 Classification of agricultural vs. non-agricultural land. The term "agricultural" is used here in the same sense as the census term "land in farms". Agricultural land includes annually cultivated cropland, biennially cultivated land such as clover or alfalfa fields, non-cultivated pasture, hayland, farm woodlots, and farmsteads.

2 Classification of cultivated vs. non-cultivated land. Cultivated land is a subset of agricultural land, while non-cultivated land may or may not be agricultural. Non-cultivated land includes biennial cropland, wild pasture, woodlots, etc.

3 Identification of the optimal spectral band(s), season(s), and combinations for interpretation of agricultural land use features.

4 Identification of the smallest useable data cell size.

5 Classification and identification of microfeatures associated with the agricultural landscape, such as farmsteads and feed lots.

These five problems provide the focus for this investigation which is designed to follow Minnesota agriculture through the 1973 harvest period. Thus, results described here must be viewed as very preliminary.

Methodology

The geometric and monochromatic appearence of individual fields on projected, single band 70mm bulk MSS film positives formed the basis of interpretation methodology. Because each field tended to be in a different stage of plant vigor, the resulting tonal variation made individual field identification a simple task.

The separation of cultivated from non-cultivated land presented a difficult interpretation problem requiring a special methodology. Freshly plowed fields are visible on early fall imagery. These fields appear at the dark end of the tonal spectrum because of the high energy absorption of rough, moist, vegetation-free surfaces. An aggregation of monthly maps of freshly plowed fields would produce the total area of cultivated land in a given county, if cloud-free sequential coverage were available throughout the fall and spring plowing seasons. The total southern Minnesota plowing season covers at least part of seven months: late August, September, October, early November, April, May and part of June. The probability is low that cloud-free sequential coverage would be available for such a long period. Accordingly, a secondary hypothesis is advanced that information lost due to cloud cover in one month could be picked up the next, because plowed fields would continue to appear dark until the leaf-on of new crops in the spring.

The aggregation system described above is necessary because it is impossible to classify cultivated and non-cultivated land visually, in the manner of conventional aerial photo interpretation. This problem will be discussed in further detail.

Procedures

1 Test sites were selected on three criteria: intensively farmed areas, covered by a good sequence of cloud-free imagery and importance to Minnesota Department of Natural Resources for wildlife habitat studies. Nicollet and Jackson counties in south central Minnesota were chosen for these reasons. Both counties specialize in corn and soybean production, although other crops are raised in lesser quantities.

2 Interpretation was accomplished by projecting each image with a lantern slide projector to the scale 1:125,000. (Freshly plowed areas were mapped for each image available.)

3 Aggregation of plowing maps at the end of the spring plowing season produced a master map.

4 Field checking tested the results as shown on the final map.

Results

The classification of agricultural and non-agricultural land is a trouble-free operation. The agricultural boundary may be identified with speed and precision. For example, the rugged forested topography of the Minnesota and Des Moines river banks stands in sharp visual contrast to surrounding agricultural lands. Minnesota bottomland forests are too dense to be suitable for grazing, so these lands are clearly non-agricultural.

The classification of cultivated and non-cultivated land yielded mixed results. Incomplete coverage presented a major handicap, because it did not prove possible to pick up missed information at a later date. As the soil of plowed fields dries and weathers, its reflectance increases and it appears light grey on the image, thus, gradually becoming indistinguishable from dead or wet fall vegetation. Hence, incomplete coverage resulted in an undercounting of cultivated areas. In addition, some fields were counted twice, as spring harrowing of fall plowed fields cannot be distinguished from actual spring plowing (see attached maps).

Aggregation of periodic interpretations of cultivated land is necessary because the conventional photo interpreter's clues of vegetation texture and land slope are not present in ERTS imagery. Crops and natural vegetation cover may reflect with equal vigor, or two fields of the same crop may appear different due to soil factors, time of planting, etc. Hilly areas are often maintained in natural cover for light grazing and erosion control, hence slope is an important information item in stereoscopic photo interpretation.

Aggregation of periodic interpretations of cultivated land proved to be a reasonably accurate method. Interpretation results were compared to ground truth obtained by field-checking. Field checking procedures consisted of recording the plowed or non-plowed condition of each of the 298 forty acre data cells observable from either side of selected section roads. When interpretation results are plotted against field checking results, the following table is obtained:

		ERTS Plowed	ERTS Non-plowed	% Correct
Field Checking	Plowed	A 254	B 12	95%
	Non-plowed	C 13	D 19	59%

Image 1022-16373 August 14, 1972

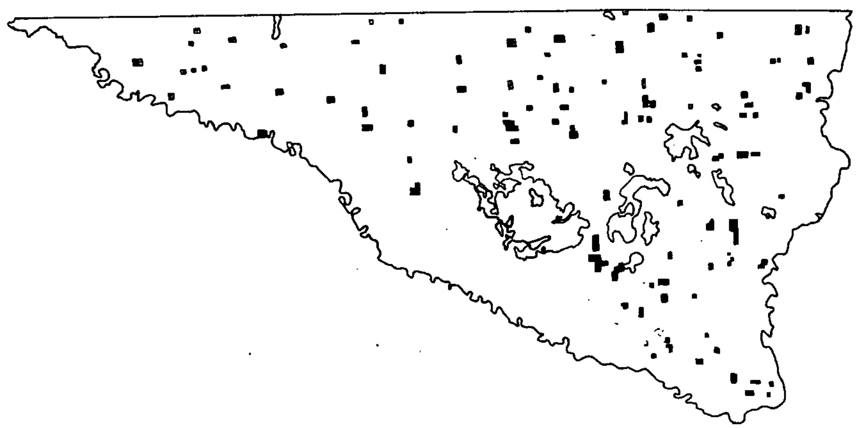


Image 1057-16328 September 18, 1972

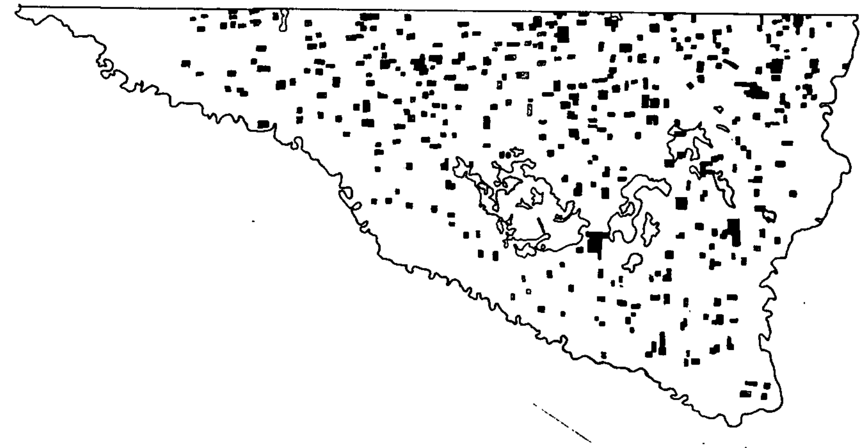


Image 1076-16375 October 7, 1972

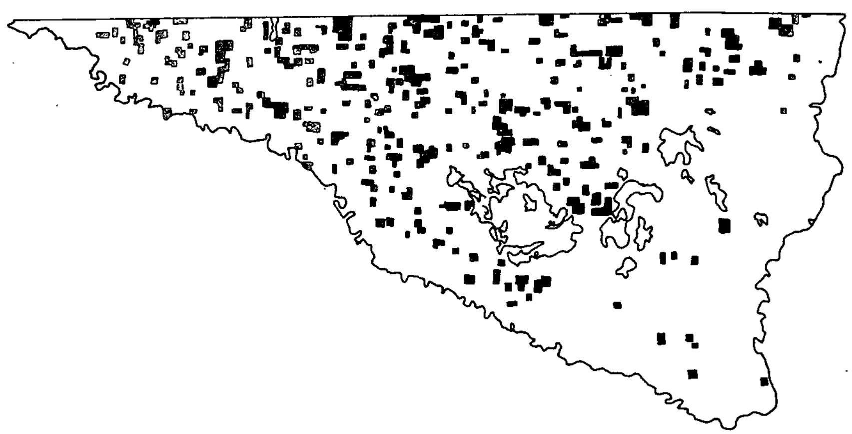
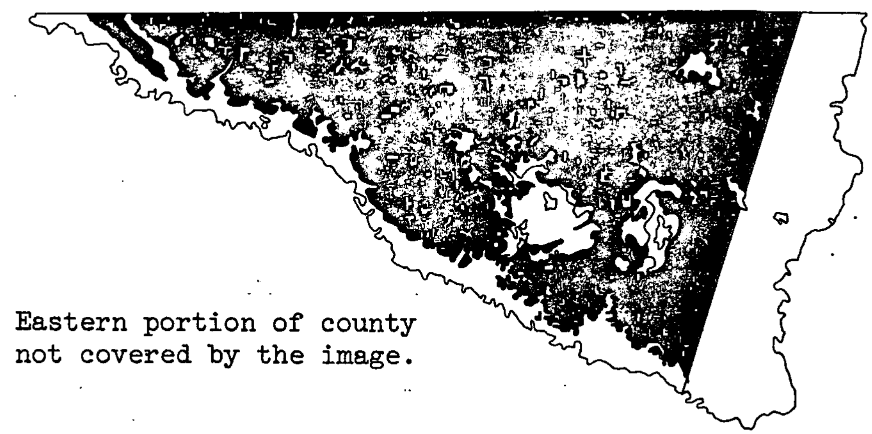


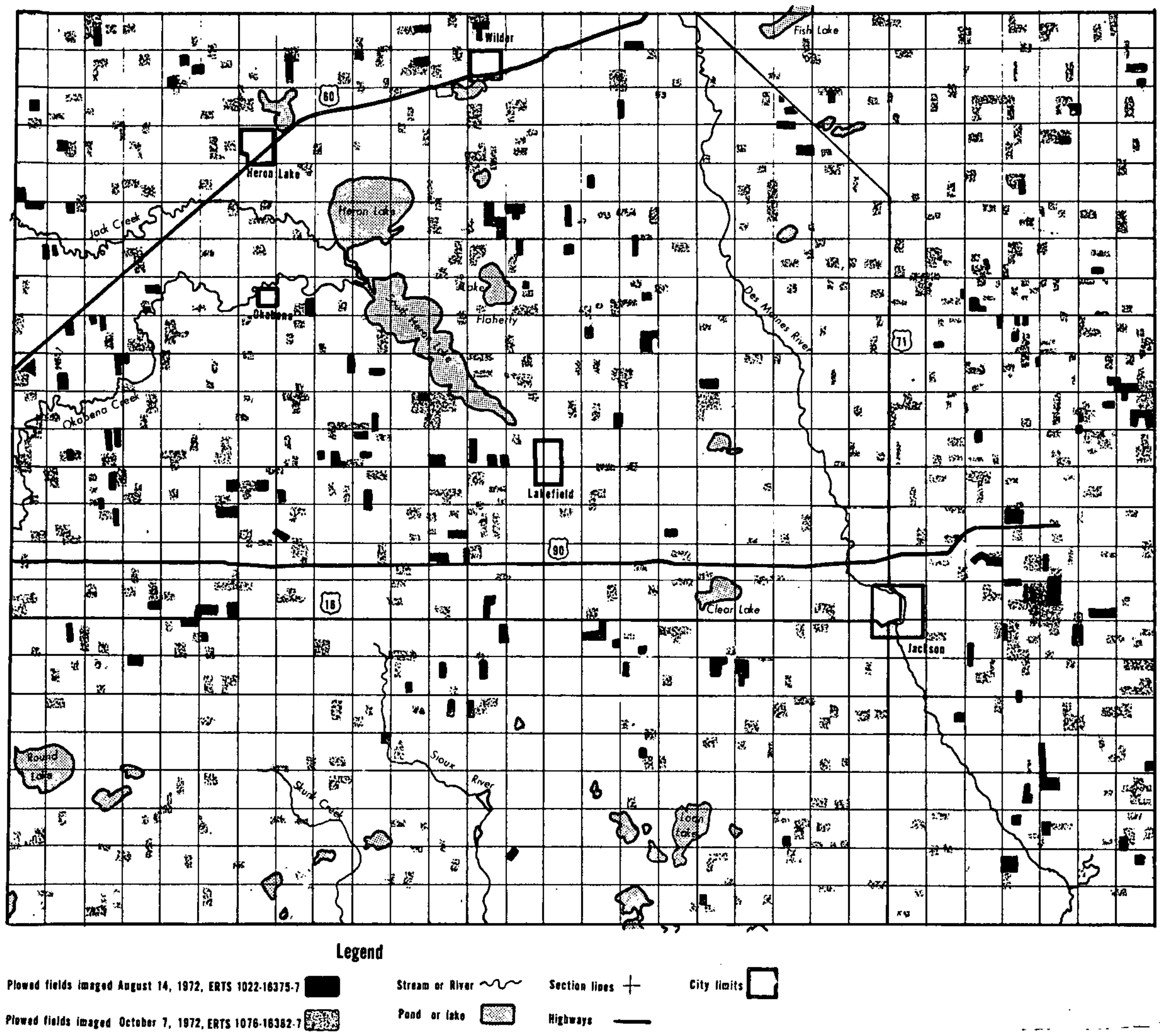
Image 1310-16383 May 29, 1973



Plowed Fields Nicollet County, Minnesota

Scale: 1 inch = 9.72 miles

FALL PLOWING IN JACKSON COUNTY, MINNESOTA



Scale: 1 inch = 4.93 miles

Boxes A and D represent the number of 40 acre cells in which ERTS interpretation and field-checking observation agreed, whereas boxes B and C record the number of errors resulting in information contradictions. The 92% level of agreement between ERTS interpretation and field observation was made possible by a fortunate series of cloud-free imagery in key months, particularly late May.

Band 7 provided the highest degree of contrast; and, it proved to be the most useful spectral band for mapping agricultural land use. All snow-free imagery contributes to the aggregation process, showing agricultural land in the various stages of the cultivation cycle. In Nicollet County, late May imagery reveals the largest amount of bare cultivated land of any one month. The greening of natural vegetation, alfalfa, and small grains precedes the greening of the dominant row crops.

The fourth classification problem is to establish the smallest usable cell size. Fields as small as 10 acres may be observed in good contrast conditions, so the use of the MLMIS 40-acre data cell is feasible with ERTS imagery.

Two types of microfeatures relating to agricultural land use are visible on ERTS imagery. Individual farmsteads may be seen in certain circumstances. Snow cover shows some farmsteds as black dots, perhaps because of building roofs and dark snow-free branches of shelter belt vegetation (MSS Image 1166-16382-7). Spring imagery shows farmsteads as white dots, reflecting the leaf-on of shelter belt and shade tree vegetation which precedes crop leaf-on (MSS Image 1310-16383-7). In addition, spring imagery reveals a scattering of seasonal potholes in Jackson County (MSS Image 1310-16390-7). These small, short-lived ponds are important in waterfowl management. Most potholes in the two study areas have been destroyed by artifical drainage.

Cost Factors

Interpretation time in outlining plowed fields or the agricultural land border averaged 25 minutes per county, or 2 minutes per township. The small scale of ERTS imagery lends itself well to quick scanning for one type of feature. Interpretation time thus can be less than for conventional aerial photography, provided the ERTS interpreter is looking for a clearly defined set of image content information. In general, it might be a time and labor saving procedure to scan large areas with ERTS imagery, and if problem areas are found, take a more detailed look with conventional air photos.

Liason with Outside Data Users

The Minnesota Department of Natural Resources, Bureau of Environmental Protection has expressed strong interest in using agricultural land use data obtained from ERTS imagery as a source of information for game management decision-making. Three major possible uses emerged in a meeting of July 6, 1973:

1 Location of the present agricultural frontier is important in game management. Marginal farming areas may be in a state of flux. Absence of plowing in formerly cultivated areas might suggest farm abandonment, as would the disintegration of geometric appearence, and tonal contrasts of fields. Advances of the agricultural frontier could be mapped by the reverse procedure.

2 ERTS imagery seems to be a promising method for monitoring illegal wetland drainage, a major wildlife conservation problem in Northwestern Minnesota. Comparison with old aerial photos will reveal advances of cultivated land at the expense of wetlands.

3 Fall plowing is a major concern of game bird managers, because plowing strips the land of winter cover. Pheasant populations have plummeted in intensely farmed areas such as Jackson County. The extent, time, and location of fall plowing over wide areas might be useful information in selecting game refuge sites.

Work in the Next Reporting Period

The next reporting period will be used to complete the evaluation of ERTS-1 applications to agricultural land use. By early fall sufficient experience should allow a full scale test of the final agricultural classification along with other land use classes in the Twin Cities Metropolitan area. This test will include the entire process from image interpretation to data entry in MLMIS.

ERTS-1 Applications to Classification and Mapping of Water Resources in Minnesota

Dwight A. Brown, Ralph Sanders, Jack Flynn, and John Harrington

Mapping and classification of Minnesota surface water resources with ERTS images was begun in June at which time sufficient state coverage had been received to allow the elimination of test areas where a low frequency of cloud free imagery was available. Two areas have been singled out for study: a seven county area in West Central Minnesota including Big Stone, Douglas, Grant, Pope, Stevens, Swift and Traverse counties and Northeastern Minnesota including St. Louis, Lake, and Cook counties. Work thus far has been confined to the West Central test area.

To proceed toward the goals of this study in as orderly a manner as possible it is necessary to identify the data needs of agencies that make decisions concerning Minnesota surface water resources, to examine ERTS applications to these needs, to identify and solve any technical problems and finally to evaluate the results. The following work is the most preliminary kind but progress has been made in the area of state agency cooperation in definition of information needs and solving interpretation problems.

Determination of Minnesota Water Data Needs

At the outset of the ERTS water study, the desirability of linking the study of ERTS imagery to water data needs for the State of Minnesota was noted. To this end, the published literature on state water resources and management, particularly that published by the Department of Natural Resources was surveyed. Generally, this perusal highlighted an absence of centralized authority for the collection of state water data, and such data as have been gathered are not of consistent quality. Further inquiry and contact demonstrated an interest on the part of some administrative agencies in determining to what extent the ERTS imagery could be used to upgrade data files. Overall, we have found three agencies whose authority or programs indicate that ERTS imagery could be used to improve the data base upon which they must act. (i) Department of Natural Resources (DNR), State of Minnesota. In discussions with DNR, we noted their interest in the establishment of a central data file, upon which the various divisions within the Department could draw for their specific data needs. Present practice is that data are collected as needed by each division on an _ad hoc_ basis. Since our research indicates some overlap of data need in terms of the statutory functions of each division, and since DNR is interested in eliminating costly duplication of information collection, a strongly rationalized water inventory contained in a central data file is desirable. Some of the file content could be supplied through ERTS imagery.

DNR administers several programs to which the ERTS imagery potentially may be applied. Legal matters arising from the draining of shallow lakes for cropping and for additions to local taxation revenues can be addressed through the monitoring of drainage activities. Presently there is no systematic surveillance of lake drainage. Since lake drainage also involves habitat destruction, waterfowl and fish management functions could be served through improved data sources. DNR surveillance of water pollution and other aspects of water-related environmental modification could be more fully articulated through improved data. Monitoring of shoreline changes through natural processes or development are other functions which have been specifically mentioned as problem areas in which ERTS imagery might prove helpful.

(ii) Department of Highways of Minnesota. The Highway Department is responsible for the production and updating of county highway maps for the state. These maps depict highways, other cultural information, and information on the location of water bodies within each county. Having been constructed from aerial photographs, these maps are problematical with respect to scale inconsistencies, and the sporadic supply of aerial information has led to outdated mapped interpretations of lake existence, location, size, and shape. Preliminary analysis suggests that the ERTS imagery could be used to improve the water information on these maps.

(iii) Bureau of Sport Fisheries and Wildlife, United States Department of the Interior, Fort Snelling, Minnesota. This agency administers a program of wetland acquisition and management in the western counties of the state, and could use data relating to seasonal lake acreage changes as well as a general inventory of lake occurence and present wetland use.

<u>General Data Uses</u>

Distilling the information given above, there are two broad categories of data use, both of which may be partly supplied by ERTS imagery:

(i) State lake inventory. The various agencies concerned with water resources require a basic lake inventory for the State of Minnesota. Such an inventory should provide an accurate assessment of the number and distribution of lakes by county. ERTS imagery could supply verification for the existing inventory, as well as providing additions and corrections to it.

(ii) State lake classification. Presently a range of lake classifications are used, and each classification tends to be specific to the uses for which it was designed. If a set of lake-diagnostic variables could be compiled, such further classifications as needed could be constructed. With this in mind, divisions within DNR were asked to provide a list of data needs and these lists, abridged to include only those variables for which ERTS imagery is potentially useful, includes lake size and shape, location of lake inlets and outlets, water depth and clarity, the presence of seasonal algal blooms, the date of freezing, and the way in which some of these attributes vary (eg., shoreline changes) on a seasonal or annual basis.

<u>Application of ERTS Imagery to Lake Inventory and Classification</u>

To date, viewing of the imagery has been confined largely to those areas in the state for which data needs are rationalized, and for which high quality imagery exists. On a county-by-county basis, particular attention has been paid to those places for which high quality area duplications exist, in order to study seasonal change.

Preliminary viewing has been confined largely to the following locations (image identification noted):

Location	Band; Date
Cook, Lake Counties	combined; Aug. 12 & Dec. 16, 1972
Duluth; St. Louis River	combined; Oct. 6, 1972
St. Croix River; Mille Lacs	combined; Oct. 6, 1972
Mahnomen, Clearwater Counties	combined; Aug. 16 & Oct. 26, 1972
Itasca County	combined; Oct. 7, 1972

For these images, good examples of differential water clarity and the presence of turbidity plumes can be found. Some limited analyses of water depth could be conducted, and several evidences of changes in shoreline shape have been noted.

Detailed viewing has been undertaken in a seven county area in West Central Minnesota. The following images were utilized:

Image I.D.	Band	Date
E-1077-16431	6 & 7	Oct. 8, 1972
E-1311-16435	6 & 7	May 30, 1973

Using appropriate county highway maps for scale consistency and for locating specific areas on the projected ERTS images, a basic lake inventory series of maps was developed. At present, a complementary series at seasonal intervals is being drawn for comparative purposes. Based on the seven county work, the mapping time for each county, excluding time used superimposing the ERTS images on the highway maps, ranged from a minimum of one-half hour to a maximum of two and one-half hours, depending on the complexity of lake patterns.

Several features of this detailed analysis point to the continuing promise of the ERTS imagery for use as a basic water data source. Major shape differences between the county highway maps (Traverse Co., 1964; 1969) and the corresponding ERTS image (E-1311-16435; Band 7, May 30, 1973) have been found for the extensive Lake Traverse. The superiority of Band 7 images as compared to conventional high altitude panchromatic aerial photography for discerning water-land boundaries in shallow water areas is clearly exhibited.

The Lake Traverse example is a specific instance of the general finding that the ERTS imagery is an effective alternative to the highway map which is often used as a source of lake information. The discrepancies are far too numerous to itemize in this report. But it follows that a basic Minnesota lake inventory could be constructed from the imagery if complete coverage were available, since the present inventory does not reflect the number and location of lakes with the precision so far attained using ERTS imagery.

It seems that an approximate ten acre threshold viewing size for small water bodies generally holds throughout the study area, but there is some variation depending on lake depth, image quality, and spectral band. This is a matter of on-going assessment. By extension, it also holds that the measurement of changes for small lakes is a subject of less confidence, since two or more initial interpretations are involved. However, it should be noted that an early estimate of minimum visibility of river widths of 300 feet should probably be revised downward to approximately 200 feet, at least for high quality imagery. Using the May 13, 1973 image of Norman and Polk Counties (I.D.: E-1294-16492), portions of the Red River narrower than 300 feet are visible.

Band 7 imagery is best for constructing lake maps, since water/non-water contrasts are sharpest. But even with Band 7 imagery, there remain some problems of discrimination between lakes and cloud shadows, and between lakes and freshly plowed fields. In the latter case, discrimination between the two is based on the geometrical regularity of the plowed field, and with reference to lake locations on the county maps. The plowed field - lake discrimination is also aided by color combining multiple season images that include both frozen and ice free conditions on lakes. Scene corrected images also relieve this problem to a degree and it is hoped similar or better results will be achieved from linear gray scale images.

Technical Problem

The inadequacy of the county highway base maps is reflected both in the erroneous location of lake positions, and scale inconsistencies both within and between maps. A question arose as to whether the scale inconsistency in itself could produce lake-location mapping errors in excess of those created through image projection to the scale of 1:125,000 (discrepancies from the center to the periphery of the projected image). An ensuing test showed that projection distortion is small relative to the map distortion. However, the problem of accurate manual registration of ERTS-1 images on maps remains a problem.

The measurement of projection distortions could be facilitated with a finely machined grid pattern which, if projected, could provide a measurement basis for these distortions. The construction error in currently available grids vastly exceeds projection distortions.

General Comment

Based upon the applied work to date, the ERTS imagery is equal or superior to existing data sources for macro-scale water phenomena (medium size lakes and larger objects of study). At micro-levels, individual interpretation assumes a larger proportion of the variation in overall mapping, and reliance on additional independent data sources increases. Continuing assessment of ERTS imagery should therefore emphasize macro-scale questions. Additionally, the imagery as a data source for monitoring short term (seasonal or annual) changes in water-related phenomena should be stressed, since comparable data sources do not exist.

Clearly, the most elemental expressed needs of DNR, periodic surface water inventories, can be achieved with ERTS-1 imagery at an acceptable level of accuracy and at low interpretation cost.

Future Work

Work in the next reporting period will focus on completing evaluation of ERTS-1 imagery as a basis for a completed surface water inventory and classification. Mapping of surface waters in the 7 county West Central Minnesota test site has been completed and evaluation of the mapping has just begun. The second test area, North Eastern Minnesota, will also be mapped. Pending satisfactory rapid completion of these two test areas and the development of a list of data user identified important variables that can be extracted from ERTS-1 imagery a complete county by county inventory of the lakes for the entire state will be attempted.

During this reporting period several meetings have been held with Minnesota DNR personnel. Several more are scheduled for the purpose of completing the above mentioned list of variables that are useful in planning and are implemented in the management of surface water resources. The local office of Federal Bureau of Sport Fisheries and Wildlife is cooperating in this effort.

The employment of a complete hydrologic year of ERTS-1 imagery is intended in order to examine surface water dynamics. This work will be completed in December 1973 and will deal with the costs, quality, and techniques for extracting surface water information for planning and management.

Applications of NASA High Altitude Aerial Photography to Minnesota Soils Problems

Dr. Richard Rust

A study was made in the Red River Valley landscape (glacial Lake Agassiz) to determine feasibility of using density slicing techniques to delineate and measure extent of soils having calcareous horizons at or below the surface (Calciaquolls). Color infrared imagery was obtained by an RB-57 aircraft (NASA) transect of an area crossing Norman, Mahnomen, Clearwater and Hubbard counties (see figure 1). The time of flight (June 6, 1972) provided a near maximum in non-vegetated surfaces.

Ground truth was established from a recently completed detailed soil survey in the Norman county portion of the transect. The scale of mapping was 1:15,840 whereas the imagery scale was 1:60,000 but appropriate enlargements of the imagery to about 1:32,000 facilitated comparisons. In several selected areas representing different soil associations and, to some extent, different cultural conditions field observations were made to compare the color-coded density 'maps' with the previously delineated soil boundaries.

Film optical density was sliced into eight levels with the equipment available (ISI Model VP-8 Image Analyzer).

Because the cultural history and especially the cultural conditions at the time of flight are reflected in the film densities it was necessary to interpret the color-coding according to the nature of the cultural conditions. However, after separating the cultural situations into a few categories (bare ground, emerging small grain, and stand over legume or permanent pasture) the interpretations were much improved.

In soil areas of complex patterns, e.g. of calcareous and noncalcareous surface horizons, the color-coded density not only indicated this pattern clearly but the capability of quantitatively assessing the proportions of each component in the complex pattern was developed.

It was also found that certain soil boundaries were better derived from an interpretation of the color-coded density than had been done by interpreting the panchromatic imagery.

A very real possibility exists that the examination of color-coded maps of survey areas prior to the field visit can (in the way that prior stereo-examination has) provide a useful guide to the soil mapper which will not only increase the accuracy of soil mapping, but increase the rate of mapping also.

Further experimentation and perfection of this technique is to be pursued.

ERTS-A COVERAGE OF MINNESOTA

Coverage # RB 57

Period Imaged: June 6, 1972

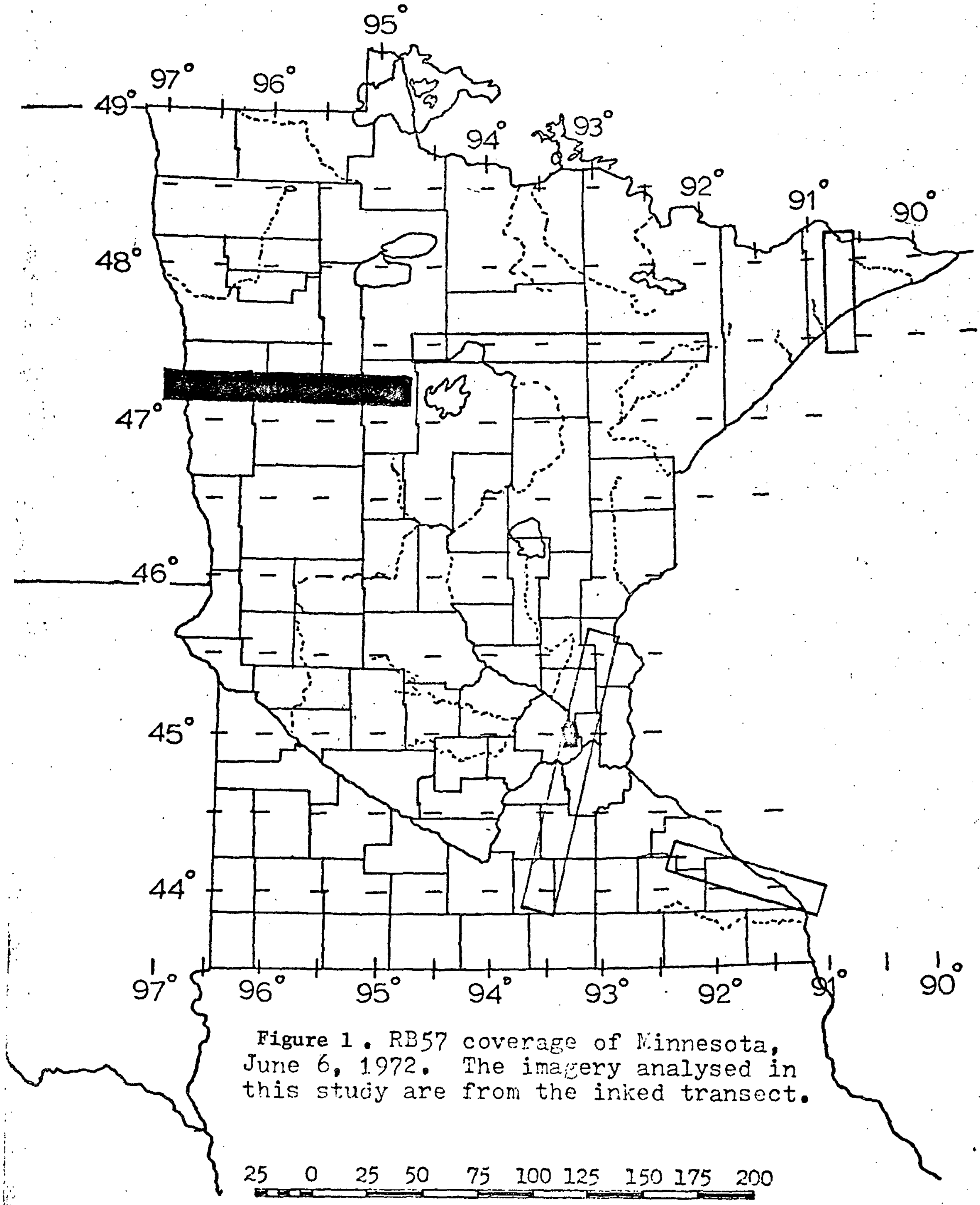


Figure 1 . RB57 coverage of Minnesota, June 6, 1972. The imagery analysed in this study are from the inked transect.

Full Scale Systems Tests of ERTS-1 Applications to Minnesota Land Use

Dwight Brown and Richard Skaggs

Introduction

The evaluation of ERTS-1 derived information is complex and can be performed in many ways and in relation to many criteria. The existing and impending resource management and regulatory powers of various state and local governmental agencies in Minnesota require that the agencies be prepared to handle massive amounts of information. It, therefore, is justified to evaluate ERTS-1 derived information on the basis of its economy, accuracy, and utility in a form that is accessible to a large number of potential users, that has sufficient information mass to interest users immediately, that provides an operational scale test of the complete data reduction procedure, and that appropriately encompasses the range of complexities of Minnesota's important land uses.

Itasca County and the Seven County Twin Cities Metropolitan Area have been selected on the basis of the above criteria. Itasca County contains lands, forests, waters, and iron mines that are controlled by the Leech Lake Indian Reservation, Itasca County, State of Minnesota U. S. Forest Service, corporations, and private individuals. Keen local interest in land based resource information on the part of planners and resource managers in the county was also an important criteria for selecting Itasca County.

The Twin Cities Metropolitan Area was selected because of the complex of urban land uses, the important surrounding agricultural land use, the surface water resources in an intense population pressure zone, and the dynamics of urban associated land uses. The need to monitor condition and change is particularly important here because there are so many overlapping jurisdictional powers. Also the interests of nearly half of the states population are involved directly.

Progress and Future Work in Itasca County

The initial phase of the Itasca County project was the selection of a suitable test area to work out the problems that arise when first integrating operational definitions for different land use classes derived independently.

The test area included 28 regular and 8 irregular townships in the southeastern part of the county. This area covers just over one third of the county and includes the widest variety of land use classes.

The initial phase of land use mapping has been completed and was carried out in several steps as follows:

1 Analysis of imagery to determine what dates, bands, and multi-spectral or multi-seasonal color comb ined images are best. While this problem may seem to have been solved in earlier work, it must be remembered that some techniques were developed in different locations, available imagery is not all of the same date, and the imagery is not all of the same quality. Furthermore, the image inventory is continually expanding to include new time periods.

2 Towns outside of the Mesabi Iron Range area were mapped from projected band 7 bulk MSS 70mm film positives for January 5, 1973. This image was used to maximize the snow enhancement of shadows. This step took one half hour.

3 Mine features and mine area towns were mapped from multi-season color combined slides for October 7, 1972 and January 5, 1973. Four and one half man hours were required.

4 Forest types, open areas, and wetlands were mapped from October 7, 1972 color combined slides. This phase required 12 man hours.

5 Surface water was mapped from projected Band 6, Bulk MSS 70mm positive imagery for October 7, 1972 and required 2 man hours.

6 Because the forest interpretation was mapped independently in the Institute of Agriculture Remote Sensing Laboratory and the towns, extractive and water were mapped in the MLMIS laboratory, it was necessary to adjust discrepancies, gaps and overlaps in information. This step took about 1/2 hour on the part of 3 men or 1.5 man hours.

This complete interpretation and mapping time was 20.5 man hours for an area of more than 1100 square miles. For purposes of comparison of the ERTS derived information with the cost of producing the existing MLMIS data it is necessary to carry the work one step further to the data coding for computer entry. This step has been carried out for one township and required about .75 man hours. Considering the relative complexity of this township the estimated coding time for the 1/3 county test area would be 15 man hours.

The MLMIS high altitude panchromatic photo interpretation and coding time are reported in clock hours for work teams of two or three men. Coding was done directly from interpreters calls so no intermediate map was produced. If we can assume an average of 2.5 men in the team, the cost in man hours would be 37.8 man hours as opposed to 35.5 projected from ERTS-1. While very close, these figures can be quite misleading. A number of very important non-quantifiable differences exist.

1 The detail of data extracted form ERTS was much greater. Forests were broken down into 4 classes with ERTS, where only one was used in the original MLMIS base. Three kinds of water features were identified on ERTS and only one in MLMIS. Three kinds of mime features were identified on ERTS as opposed to one from the MLMIS.

2 It is feasiable to incorporate several seasons of monoscopic, multi-spectral coverage with ERTS whereas only one season (leaf off spring) of stereoscopic, panchromatic photography was available for the MLMIS work. Thus the technologies are not comparable.

3 An estimated four man hours reduction in interpretation time could be achieved if the work was done by one interpreter and lakes were mapped first. This of course implies that the interpreter has a very broad range of experience. Thus more training and higher cost personnel of uncertain availability would be needed. At this stage a multi discipline team approach still seems to be the best solution despite the slight time disadvantage.

Transferring this preliminary mapping experience from Itasca County to other counties in Minnesota is difficult. Much of the state has a much smaller variety and simpler texture of land use patterns, thus making the coding process easier. Coding time is also relatively longer in Itasca County because of irregularities in the public land survey. Both of these problems presumably also apply to the original MLMIS land use interpretations.

To date one township has been coded for debugging the CRT display keyboard entry and edit system for MLMIS updating. The main technical problem is simply expanding the number of classes of land use. This requires only a minor programming change. The Itasca data file is currently on a disk storage file for ready access to the information base of any one half township at a time.

The preliminary forest type interpretation maps are being evaluated for accuracy and utility by a wide variety of forest resource managers in Itasca County. This work is being carried out by the Institute of Agriculture Remote Sensing Laboratory, under the direction of Dr. Merle Meyer. When both the forest and non-forest work is complete and evaluated, the maps will be coded for entry into MLMIS and the data will be placed on the system where it will be accessable to users. Appropriate information will also be placed on computer drawn maps for planning, management and publication.

Twin Cities Metropolitan Area Systems Test Area

A preliminary map of the urbanized portion of the seven county area has been completed and is included elsewhere in this report. This map will be evaluated by planning and land management personnel in the area and necessary changes will be incorporated into a full scale test that will include all land uses in the area. The resulting complete map based on the best of the images appropriate to each category of land use will be coded and an active disk file will be set up in a manner similar to Itasca County. The tentative schedule calls for completion of the system set up so that users can become acquainted with the system and evaluate the information during this fall. A final report based on this evaluation will accompany the final report.

COOPERATION

Growing ties among personnel directly associated with this project and personnel from, Minnesota Departments of Highways, and Natural Resources, Honeywell's ERTS program, U.S.D.I. Bureau of Sport Fisheries and Wildlife, U.S.D.A. North Central Forest Experiment Station, Metropolitan Council, and numerous regional, county, and local planning and resource managers has facilitated a growing awareness of ERTS materials. It is now beginning to provide an input of ideas that are essential to development and evaluation of a complete and usable information system.

RECOMMENDATIONS

The rapid and timely production of single band and color products in the form of 2"x2" super slides made available through EROS Data Center would be an important step toward expanding the use of ERTS products. The role of these products in education has been grossly under played if not totally ignored.

The quality of NDPF color products might be improved by attempting to reduce the dominance of the red emulsion layer. It often seems to mask the detail seen on the bulk band 5 images. The desireability of a dominant red emulsion probably has some important geographic and seasonal variations.

APPLICATION OF ERTS-1 IMAGERY TO STATE-WIDE

LAND INFORMATION SYSTEM IN MINNESOTA

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July 1973
Progress Report for Period of January - June 1973

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

ERTS IMAGE DESCRIPTOR FORM
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DATE July, 1973

PRINCIPAL INVESTIGATOR Sizer, Minn. - S.P.A.

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	agriclt.	water	urban	
1022-16373-7-S	x			South Central Minnesota
1022-16375-7-S	x			South Central Minnesota
1057-16328-7-S	x			South Central Minnesota
1076-16375-7-S	x			South Central Minnesota
1076-16382-7-S	x			South Central Minnesota
1166-16382-7-S	x		x	South Central Minnesota
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1146-16270-7-S			x	South East Minnesota
1075-16321-5,6,7-S			x	Twin Cities
1201-16325-5,6,7-S			x	Twin Cities
1294-16492-7-S		x		Red River Valley
1310-16390-7-S		x		South Central Minnesota
1077-16431-7-S		x		West Central Minnesota
1311-16435-7-S		x		West Central Minnesota
1075-16314-5,7-S		x		Lake Mille Lacs
1095-16431-5,6-S		x		North West Minnesota
1024-16482-5,6-S		x		North West Minnesota
	extractive		water	
1075-16312-5,6,7-S	x		x	Duluth, Iron Range
1165-16314-7-S	x		x	Duluth, Iron Range
1057-16311-5,6,7-S	all features			Itasca County
1165-16314-7-S	all features			Itasca County
1076-16370-5,6-S	all features			Itasca County
1166-16373-7-S	all features			Itasca County

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